# Chapter 7

1. $P = mv = (15 \times 10^{-3}\ \text{kg})(12\ \text{m/s}) = \underline{0.18\ \text{kg m/s}}$

2. $F = \dfrac{\Delta P}{\Delta t} = (1000\ \text{kg/s})(60{,}000\ \text{m/s}) = \underline{6 \times 10^{7}\ \text{N}}$

3. From the conservation of linear momentum $(3.4\ \text{kg})(10.0\ \text{m/s}) = (80\ \text{kg})v$
$v = \underline{0.425\ \text{m/s}}$
<u>(opposite to the direction of package)</u>

4. momentum before = momentum after
$(9000\ \text{kg})(20\ \text{m/s}) = (9000 + m)\text{kg}\ (4\ \text{m/s})$
$m = \underline{36\ 000\ \text{kg}}$

5. $(15\ 000\ \text{kg})(18\ \text{m/s}) = (20\ 000\ \text{kg})v$
$v = 13.5\ \text{m/s}$

6. momentum before = momentum after
$(140\ \text{kg})(3.0\ \text{m/s}) - (90\ \text{kg})(6.5\ \text{m/s}) = (230\ \text{kg})v$
$v = -0.717\ \text{m/s}$
<u>The tackler is pushed backwards</u>.

7. Energy destroyed by friction of block and bullet is
$\mu mgd = (0.28)(1.255)(9.8)(11) = mV^2/2 = (0.5)(1.255)V^2$.
$V = 7.77$ m/s. Thus $(1.255)(7.77) = (0.015)v$.
$v = \underline{650\ \text{m/s}}$.

8. $(0.022)(340) = (2.422)V$. $V = 3.09$ m/s. $h = V^2/2g = (3.09)^2/2/9.8 = \underline{0.49\ \text{m}}$.

9. $0 = 57\ mV + m(3.8 \times 10^5\ \text{m/s})$. $V = \underline{-6.67 \times 10^3\ \text{m/s}}$, i.e. in opposite direction.

10. $(0.01)(400) = 2V + (0.01)(350)$. $V = \underline{0.25\ \text{m/s}}$.

11. Use conservation of momentum. $(700)(6.2 \times 10^3) = (350)v + (350)(v + 2.45 \times 10^3)$.

(a) $v = \underline{4.98 \times 10^3 \text{ m/s}}$. $V = \underline{7.43 \times 10^3 \text{ m/s}}$ in original direction

(b) $\Delta E = 0.5(350)(4.975 \times 10^3)^2 + 0.5(350)(7.425 \times 10^3)^2 - 0.5(700)(6.2 \times 10^3)^2 = \underline{5.25 \times 10^8 \text{ J}}$.

12. As the rocket gasses are expelled perpendicular to the original rocket direction, the component of velocity towards the sun does not change. The component perpendicular must equal
$(120)(\tan 30°) = 69.3$ m/s.
$0 = (3300 - m)(69.3) - m(2200)$, $m = \underline{101 \text{ kg}}$.

13. $F = \Delta p/\Delta t = (0.06 \text{ kg})(65.0 \text{ m/s})/(0.03 \text{ s}) = \underline{130 \text{ N}}$. No.

14. $\Delta p/\Delta t = (0.145 \text{ kg})[50 \text{ m/s} - (-35 \text{ m/s})]/(5 \times 10^{-4} \text{ s}) = \underline{2.47 \times 10^4 \text{ N}}$.

15. (a) $(90 \text{ kg})(5.0 \text{ m/s}) = \underline{450 \text{ kg . m/s}}$.

(b) $F\Delta t = \Delta p = \underline{(450 \text{ kg . m/s})}$.

(c) $\Delta p/\Delta t = \underline{450 \text{ N}}$.

16. $\Delta p = mv \sin 45° - (-mv \sin 45°) = \underline{2\, mv \sin 45°}$.

17. Area under curve is 9 squares = $9(50 \text{ N})(0.01 \text{ s}) = \underline{4.5 \text{ N}\cdot\text{s}}$. $mv$ = Impulse.
$v = (4.5 \text{ N . s}/(0.060 \text{ kg}) = \underline{75 \text{ m/s}}$.

18. This question can only be worked if we neglect energy loss at initial impact with the ground. Use conservation of energy $mg(h + 0.6 \text{ m}) - (170 \times 10^6 \text{ N/m}^2)(3 \times 10^{-4} \text{ m}^2)(0.6 \text{ m}) = 0$.
Hence $h = \underline{51.4 \text{ m}}$.

19. $(0.44)(4.5) = 0.22V + 0.44v$. Energy: $(0.5)(0.44)(4.5)^2 = (0.5)(0.22)V^2 + (0.5)(0.44)v^2$.
To avoid unnecessary algebra note $V = 0$, $v = 4.5$ m/s are a pair of solutions for these equations. We just need to find the other pair. If we eliminate v by using $v = 4.5 - 0.5V$ in second equation as $V = 0$ is a solution the quadratic is simple.
$1.5V^2 - 9V = 0$, i.e. $V = \underline{6.00 \text{ m/s}}$, $v = \underline{1.50 \text{ m/s}}$.

20. (0.300 kg)(2.5 m/s) = (0.300 kg)$v_1$ + (0. 600 kg)$v_2$
(0.300 kg)(2.5 m/s)$^2$/2 = (0.300 kg)$v_1^2/2$ + (0.600 kg)$v_2^2/2$

$v_1$ = 0.83 m/s backward
$v_2$ = 1.67 m/s forward

21. In general for equal masses, $v_1 + v_2 = V_1 + V_2$, $v_1^2 + v_2^2 = V_1^2 + V_2^2$. Clearly, $v_1 = V_1$, $v_2 = V_2$ are solutions, but the interesting case is $v_2 = V_1$, $v_1 = V_2$, i.e. first ball rebounds with velocity 3 m/s in same direction as second ball was originally moving. And second ball rebounds with velocity 2 m/s.

22. Consider the problem in the rest frame of the heavy particle, i.e. a frame moving with $v_1$. The light particle hits the "wall" of the heavy particle with speed $v_1$ and bounces back with speed $v_1$. So in this frame the heavy particle has speed zero, the light particle is rebounding with $v_1$. Now transfer back to original frame. Heavy particle moves with speed $v_1$, light particle with speed 2 $v_1$. We now prove mathematically what we argued physically. Best to use momentum and mass as variables. Momentum conservation gives, $p_1 = p_1' + p_2'$. Energy conservation ($E = mv^2/2 = (mv)^2/2m = p^2/2m$) gives $p_1^2/2m_1 = p_1'^2/2m_1 = (p_1 - p_2)^2/2m_1 + p_2'^2/2m_2$. Thus $p_2' \simeq 2\, p_1 m_2/m_1$, neglecting $p_2'^2/2m_1$ term as small. Thus $v_2' = 2\, v_1$. $p_2' = m_1 v_1 - m^2 v_2$, thus $v_1' \simeq v_1$ neglecting terms $(m_2/m_1)$.

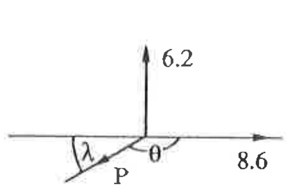
23. Proceed as in previous problem, but as now $m_1 \ll m_2$, eliminate $p_2$,
$p_1^2/2m_1 = p_1'^2/2m_1 + (p_1 - p_1')^2/2m_2$. $p_1 \simeq -p_1'$, and hence $v_1 = -v_1'$ and $v_2' = 0$.

24. Momentum: (0.46)v = $m$(v/2) + (0.46)$V$.
Energy: (0.5)(0.46)v$^2$ = (0.5)$m$(v$^2$/4) + (0.5)(0.46)$V^2$.

(a) Eliminating $V$, gives $m$ = 1.38 kg.

(b) Energy fraction is [0.5(1.38)v$^2$/4]/[0.5(0.46)v$^2$] = 0.75.

25.




$p = (8.6^2 + 6.2^2)^{\frac{1}{2}} 10^{-23}$ kg . m/s = 10.6 × $10^{-23}$ kg . m/s. By momentum conservation 10.6 × $10^{-23}$ cos $\lambda$ = 8.6 × $10^{-23}$. $\theta$ = 144°.

26. (a) $(0.4\ \text{kg})(1.8\ \text{m/s}) = (0.4\ \text{kg})v \cos\theta + (0.4\ \text{kg})(1.1\ \text{m/s})(\cos 30^\circ)$
$(0.4\ \text{kg})(1.1\ \text{m/s})(\sin 30^\circ) = (0.4\ \text{kg})v \sin\theta$.

(b) $v = \underline{1.01\ \text{m/s}}$, $\theta = \underline{33^\circ}$.

27. Applying momentum and energy conservation gives $mv = 2\,mV\cos\theta$, $2\,mV\sin\theta = mu$, $mv^2/2 = 2\,mV^2/2 + mu^2/2$. Solving

(a) $\theta = \underline{-30^\circ}$.

(b) $u = \underline{v/(3)^{\frac{1}{2}}}$, $V = \underline{v/(3)^{\frac{1}{2}}}$.

(c) Fraction of energy $= 2\,mV^2/mv^2 = \underline{2/3}$.

28. Momentum must be conserved in the $x$ and $y$ directions.
$\underline{x}$ $(m)(4.0\ \text{m/s}) = mv_1'$
$v_1' = \underline{4.0\ \text{m/s (in the positive } x \text{ direction)}}$

$\underline{y}$ $m(2.5\ \text{m/s}) = m(v_2')$
$v_2' = \underline{2.5\ \text{m/s (in the positive } y \text{ direction)}}$

29. Conservation of momentum perpendicular to the original direction gives $(0.4\ \text{kg})V_A \sin 30^\circ = (0.6\ \text{kg})V_B \sin 53^\circ$. $V_B/V_A = \underline{0.417}$.

). Since $4m_1 = m_2$, Eqs 7–a b & c become

$$v_1^2 = v_n'^2 + 4v_{He}'^2$$
$$v_1 = v_n' \cos\theta_1' + 4v_{He}' \cos\theta_2'$$
$$0 = v_n' \sin\theta_1' + 4v_{He}' \sin\theta_2$$

where $v_1 = 4.5 \times 10^5$ m/s and $\theta_2' = 45°$.

Second and third equations become

$$v_n'^2 \cos^2\theta_1' = v_1^2 - 8v_1v_{He}' \cos\theta_2' + 16\, v_{He}'^2 \cos^2\theta_2' \text{ and}$$
$$v_n'^2 \sin^2\theta_1' = 16\, v_{He}' \sin^2\theta_2. \text{ Therefore}$$
$$v_1^2 - 4_{He}'^2 = v_n'^2 = v_1^2 + 16\, v_{He}'^2 - 8v_1v_{He}' \cos\theta_2'$$

Thus $20\, v_{He}'^2 = 8v_1v_{He}' \cos\theta_2'$, or

$$v_{He} = (2/5)v_1 \cos\theta_2$$
$$= (0.4)(4.5 \times 10^5)\cos 45°$$
$$= \underline{1.27 \times 10^5 \text{ m/s}}.$$

$$v_n' = (v_1^2 - 4v_{He}'^2)^{\frac{1}{2}} = [4.5^2 - 4(1.27)^2]^{\frac{1}{2}} \times 10^5$$
$$= \underline{3.71 \times 10^5 \text{ m/s}}.$$
$$\sin\theta_1' = -(4v_{He}'/v_n')\sin\theta_2' = -0.97$$
$$\theta_1' = \underline{-76°}.$$

31. Momentum: $mv = (M + m)V$.
Energy: $(M + m)V^2/2 = (M + m)gh$, where $h$ = height swung.

Geometry: $h = l(1 - \cos\theta)$, $x = l \sin\theta$, where $\theta$ = angle deflected. i.e. $h = l - \sqrt{l^2 - x^2}$.
$h = V^2/2g = [mv/(M + m)]^2/2/g = [(0.02)(250)/3.82]^2/2/9.8 = 0.087$ m

horizontal displacement $x = (2hl - h^2)^{\frac{1}{2}} = \underline{0.63 \text{ m}}$

'2. (a) $KE = mv_1^2/2$
$$\Delta KE = KE - (1/2)(m + M)v'^2 = KE - [m^2/(m + M)]v_1'^2/2$$
$$\Delta KE/KE = \underline{1 - m/(m + M)}$$

(b) $\Delta KE/KE = 1 - 0.01/(.25) = 0.96$.

33. Use kinetic energy $= p^2/2\,m$. Let $m$ be the smallest mass. Then as momenta are equal $(p^2/2\,m) + (p^2/3\,m) = 4500$ J. Hence $p^2/2\,m = (3/5)(4500)\text{J} = \underline{2700 \text{ J}}$, and $p^2/3\,m = (2/5)(4500)\text{J} = \underline{1800 \text{ J}}$. <u>The smallest mass acquired the largest energy</u>.

34. Conservation of momentum:
$(6.8)(9.6) = (6.8 + 8.3)\, v \cos\theta$
$(8.3)(8.4) = (6.8 + 8.3)\, v \sin\theta$
$v = \underline{6.32 \text{ m/s}}$,
$\theta = \underline{46.9°}$ to original direction of first eagle.

**35.** (a) Elastic: conservation of momentum: $m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$;
conservation of energy: $m_1v_1^2 + m_2v_2^2 = m_1v_1'^2 + m_2v_2'^2$,
or, $m_1(v_1^2 - v_1'^2) = m_2(v_2'^2 - v_2^2)$.
$m_1(v_1 - v_1')(v_1 + v_1') = m_2(v_2' - v_2)(v_2 + v_2')$
But first equation implies $m_1(v_1 - v_1') = m_2(v_2' - v_2)$.
Thus $v_1 + v_1' = v_2 + v_2'$, i.e. $e = (v_1' - v_2')/(v_2 - v_1) = 1$.
Completely inelastic collision, $v_1' = v_2'$.
Thus $e = (v_1' - v_2')/(v_2 - v_1) = 0$

(b) $v_2 = v_2' = 0$ since steel plate is heavy.
$h = v_1^2/2g$, $h' = v_1'^2/2g$.

$\underline{e} = v_1'/v^1 = \underline{(h'/h)^{\frac{1}{2}}}$.

**36.** $0 = 4uV_1 - 228uV_2$

$5.3\ MeV = \frac{1}{2}(4u)V_1^2$

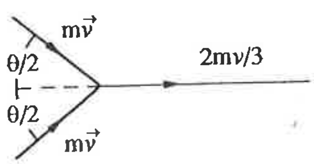
$V_1^2 = 2(5.3\ MeV)/(4u)$

$V_1 = 1.63(MeV/u)^{\frac{1}{2}}$
$V^2 = 4uV_1/228u = 0.0175\ V_1$

$KE_{Th} = \frac{1}{2}(228\ u)V_2^2$

$= 114u(0.0175\ V_1)^2$
$= 114u(0.175)^2(1.63)^2\ MeV/u$
$= \underline{0.0930\ MeV}$
Total $KE = 5.3\ MeV + 0.093\ MeV = \underline{5.393\ MeV}$

**37.** The completely inelastic collision means the two objects move off together. Hence
$2\ mv\cos\theta/2 = 2\ mv/3$, i.e. $\theta = \underline{141°}$.



38. (a) $(3)(6) + (2)(-4) = (3 + 2)V$. $V = 2$ m/s (in $+x$ direction)

(b) $(3)(6) + (2)(-4) = 3v_3 + 2v_2$.
$6 - (-4) = v_2 - v_3$.
$v_2 =$ 8 m/s, $v_3 = -2$ m/s.

(c) $(3)(6) + (2)(-4) = 2\ v_2$. $v_2 =$ 5 m/s.

(d) $(3)(6) + (2)(-4) = 3\ v_3$. $v_3 =$ 3.3 m/s.

(e) $(3)(6) + (2)(-4) = (3)(-4) + 2\ v_2$. $v_2 =$ 11 m/s.

(c) is not reasonable, because that means the two masses have to go through one another.

(d) is reasonable, the 2-kg mass is "bounced back"

(e) is not reasonable since $KE$ after > $KE$ before.

39. $X = [(12\text{ u})(1.13 \times 10^{-10}\text{ m}) + 16\text{ u}(0)]/(12 + 16) = 4.84 \times 10^{-11}$ m.

40. $$\bar{x} = \frac{(1200\text{ kg} \times 3.1\text{ m}) + (3 \times 65\text{ kg} \times 3.85\text{ m}) + (2 \times 65\text{ kg} \times 2.6\text{ m})}{(1200 + 5 \times 65)\text{kg}}$$

$\bar{x} =$ 3.15 m.

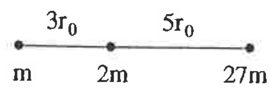
41. If your mass is (100 kg) the mass of one leg = (100 kg)(21.5 + 9.6 + 3.4)/200 = 17.25 kg.

42. Position of cm from shoulder (%) is [(6.6)(9.5) + (4.2)(25.9) + (1.7)(38.1)/[6.6 + 4.2 + 1.7] = 18.9%.

43. Measuring distance from shoulder. Upper arm cm is 81.2 – 71.7 = 9.5; lower arm cm is 81.2 – 55.3 = 25.9; hand is 81.2 – 43.1 = 38.1.
Assuming cm of upper arm is in middle this gives 19 as length of upper arm, 6.9 as height of lower arm cm and 19.1 as height of hand cm (above elbow, when joint is bent).
Thus $X$ = (170 cm/100)[(6.6)(9.5) + (5.9)(19)]/[6.6 + 5.9] = 23.8 cm from shoulder.
$Y$ = (170 cm/100)[0 + (4.2)(6.9) + (1.7)(19.1)]/(6.6 + 5.9) = 8.36 cm.
From elbow, (8.4 cm, 8.5 cm)

44. Measuring distances of cm from torso: they are (as in problem [43]) upper arm 9.5; lower arms 25.9; hands 38.1; upper legs 52.1 – 42.5 = 9.6; lower legs 52.1 – 18.2 = 33.9; and feet 52.1 – 1.8 = 50.3.
Then $Y$ = [(6.6)(9.5) + (1.7)(38.1) + (21.5)(9.6) + (9.6)(33.9) + (3.4)(50.3)]/100 = 9.39% below torso.
It will generally be outside the body.

45.




The spheres have mass, $m$, $8m$, and 27 $m$, assuming ·· are and the same density.
$X = [0 + 3(8\ m) + 8(27\ m)]r_0/[m + 8\ m + 27\ m] = \underline{6.6,}$ ..

46. Take origin as center of raft with $y$ north and $x$ west. The position of CM is
$x = y = (1000)(-15)/(8400) = -1.79$ m. Thus 2.53 m in SE direction.
If raft is free to move then CM does not change relative to water. If raft is fixed new
$Y = (1000)[-15 + (0.5)(0.8)(4)^2]/8400 = \underline{-1.02\ m}$. Thus CM is at 2.06 m 29.7° S of E.

47. $X = -(\pi R^2)(0.8\ R)/[\pi(2R)^2 - \pi R^2] = \underline{-0.27\ R}$, from the center, i.e. on the opposite direction o hole.

48. (a) Measuring from the earth,
$R = (7.36 \times 10^{22}\ \text{kg})(3.80 \times 10^8\ \text{m})/(7.36 \times 10^{22}\ \text{kg} + 5.98 \times 10^{24}\ \text{kg})$
$= \underline{4.68 \times 10^6\ \text{m from earth}}$.

(b) The earth–moon system moves around the sun in an ellipse. The earth and the moon move ar the (moving) earth–moon cm in ellipsès.

49. (a) $X = (70)(8)/120 = \underline{4.7\ m}$ from girl.

(b) He is $8 - 2 - 4.67 = 1.33$ m from CM. Therefore $(50)L = (70)(1.33)$ where $L$ is distance ol from CM. $L = 1.87$ m. So distance between boy and girl is 3.2 m.

(c) His original distance from CM was 3.33 m. When colliding, both he and girl are at $CM$, s has moved 3.3 m.

50. Final position of cm is at 2 $D$. Let $L$ be distance $m_{II}$ falls beyond this point.

(a) Then $m_I D = m_{II} L = 3\ m_I L$, i.e. $L = D/3$. So rocket lands (7/3) $D$ from original position.

(b) Then $m_I D = 3m_{II} D = m_{II} L$, i.e. $L = 3\ D$. So rocket lands 5 $D$ from original position.

51. When the man moves down the gondola will move up. The center of mass does not move.
$U_{MB} = U_{MG} + U_{GE}$
$m \rightarrow$ man, $E \rightarrow$ earth, $G \rightarrow$ gondola
Taking moment about the cm.
$M\ U_{GE} = M(U - U_{GE})$ Taking down as positive.
$M\ U_{GE} = m\ U - m\ U_{GE}$
$(M + m)U_{GE} = m\ U$

$U_{GE} = \underline{\dfrac{m\ U}{m + M}}$ upward.

If man stops, gondola stops.

52. $F = \Delta p/\Delta t = (4.3 \times 10^4)(27.8) = \underline{1.20 \times 10^6\ N}$

53. (6000)(15) = [6000 + (4 kg/min)(80 min)]v. v = 14.2 m/s.

54. Use conservation of momentum. In $x$ direction $mv_0 = (2/3)mv_x$. Hence $v_x = \underline{(3/2)V_0}$.
In $y$ direction $0 = (1/3)m(2\ v_0) + (2/3)mv_y$. $v_y = \underline{-v_0}$

Any two momentum vectors form a plane. Unless the third vector is in that plane it has an unbalanced component perpendicular to the plane, i.e. the resultant momentum could not be zero. But it must be from conservation of momentum as $p$ was zero initially.

56. (a) 0 = (150 kg)(2.35 m/s) + (2000 kg)$V$
$V = \underline{-0.176\ m/s}$ in opposite direction from astronaut.

(b) $F$(0.200 s) = (150 kg)(2.35 m/s)
$F = \underline{1.76 \times 10^3\ N}$

57. Momentum: $mv = MV - mv/3$. Energy: $0.5\ mv^2 = 0.5\ mV^2 + 0.5\ mv^2/9$. Hence $M = \underline{m/2}$.

**58.** $(10^8\ \text{kg})(15\ \text{km/s}) = (6 \times 10^{24}\ \text{kg})V$.

(a) $V = \underline{2.5 \times 10^{-16}\ \text{km/s}}$.

(b) $f = (6 \times 10^{24}\ \text{kg})(2.5 \times 10^{-16}\ \text{km/s})^2/(10^8\ \text{kg})/(15\ \text{km/s})^2 = \underline{1.67 \times 10^{-17}}$.

(c) $\Delta E = (0.5)(6.0 \times 10^{24}\ \text{kg})(2.5 \times 10^{-13}\ \text{m/s})^2 = \underline{0.188\ \text{J}}$.

**59.** Conservation of momentum: $mv + MV = 0$
Conservation of energy: $mv^2/2 = 2(MV^2/2)$
$(m/M)v^2 = 2V^2 = 2(m/M)^2v^2$, $m/M = \underline{1/2}$.

**60.** This problem is unphysical, and has no solution.

**61.** The speed of the 1.5 kg mass at the bottom of the slope is $(2gh)^{\frac{1}{2}} = [(2)(9.8)(3.6)]^{\frac{1}{2}} = 8.4$ m/s. Assuming a smooth curve to turn the mass without loss of energy, conservation of horizontal momentum gives $(1.5)(8.4\ \text{m/s}) = (1.5)v + 6V$.
Conservation of energy gives $(1.5)(8.4)^2 = (1.5)v^2 + 6V^2$. Solving gives

(a) $V = \underline{3.36\ \text{m/s}}$. $v = \underline{-5.04\ \text{m/s}}$.

(b) We may now use conservation of energy $mv^2/2 = mgh$ to obtain $h = (5.04)^2/2/9.8 =$
Distance up incline is $1.3/\sin 30° = \underline{2.6\ \text{m}}$.

**62.** When $m$ rebounds, it has speed $v_0$ (initially) back up slope. When it reaches bottom, v must be greater than $V$ (the speed given $M$ in the collision) to collide with $M$ again. So, we need $v \geq V$ to meet the stated condition.
Set $v = -V$ as threshold.
$mv_0 = -mv + MV = (M - m)v$

$$\frac{1}{2}mv_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}MV^2$$

$mv_0^2 = mv^2 + Mv^2 = (m + M)v^2$
Solving, $M = 3m$ at threshold. In general, need $M \geq 3m$